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THE FERTILITY OF CECROPIA EGGS IN RELATION TO THE MATING PERIOD.

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Nature is lavish in her provision and wasteful in her economy. It is often difficult to tell where her reckless generosity ends and where the delicate limitations for the good of the species begin; in how far the individual shapes the race, or how far natural selection or other agencies eliminate the individuals in unnoticed millions in order to make the species the unit.

The *Cecropia* moth lays, on an average, about 300 eggs. After a free and natural mating, a considerable portion of these are found to be infertile. May it be that the prolific production thus tends to defeat itself by causing the great elimination?

We have also found[1] that a large per cent. of the females die still retaining a considerable number of their eggs, which it seems they have not sufficient strength or lease of life to deposit. This waste might also appear the direct result of the strain of producing such a large mass of ova.

Now we know[2] that the act of mating itself seems to curtail the life of the female by several hours, but even under these conditions of abbreviated time, oviposition is more nearly complete than when the individual remains unfertilized. Hence we see that while copulation itself works against the individual in curtailing its life, it works for the race in, in some way, increasing her power of bringing forth her young. In this far we find copulation, besides being a biological necessity, an actual economy in the production of a next generation.

Now when we consider these phenomena in connection with the fact that on an average 21 hours, or about 9 per cent. of the whole life of the insect, is normally spent in mating, the simple questions at once arise:

[1] *Trans. Acad. Sci. St. Louis*, Vol. 20, p. 314.

[2] *Journ. Exp. Zoöl.*, Vol. 12, p. 199.

Does a longer period of copulation tend to insure the fertility of all the ova? or,

Does a larger number of ova require a longer period of mating in order to insure the fertility of all?

Is there a higher percentage of fertility among the first eggs deposited than among the last? (If so, the eggs retained after death may not be such a waste after all.)

At first thought one might reasonably assume that after a mating of normal duration,[1] practically all of the ova would be fertile. A moment's reflection tells us, however, that this is not the case anywhere in the animal or plant world. But there is nothing to tell us whether a shorter period of mating will result in a lower percentage of fertility. One might reasonably expect that in an abbreviated time the amount of sperm received into the seminal receptacle would be insufficient to fertilize the normal number of ova, and even more inadequate for an abnormally large number.

Whether or not such relationships exist, the following work will tend to show.

Material and Methods.

The 70 insects (35 ♂'s and 35 ♀'s) which supplied the following data were all isolated immediately upon leaving the cocoon, and as fast as mates emerged they were placed together, a single pair in a cage. Thus promiscuous mating was securely safeguarded against. All of the insects were comparatively young when mating began; none were over 24 hours old.

Frequently a few eggs would be deposited before mating began, but these were in all cases vigilantly destroyed. Early every morning the eggs from each cage were counted and placed in a vial with a cotton stopper and labeled; this comprised the oviposition of the preceding 24 hours.

The emerging caterpillars all died in their vials. Later these, as well as the empty egg-shells, were counted, and all the eggs which had not hatched were dissected to find whether they were infertile or whether they contained an embryo. In most cases

[1] Previous investigations have led us to conclude that, in this locality at least, the species is monogamous.

all of the eggs that were shrivelled proved infertile and contained only a dried mass of yellow substance. It also usually happened that the smooth, round eggs contained a full-formed insect. There were a few exceptions in each class, however, and external appearance was not relied upon, but all eggs were dissected. Again a number of fertile eggs had openings of various sizes, sometimes too small to free the insect, and at other times perfectly cut, but the caterpillar it seems felt not inclined to leave the shell. These were in every case counted with those which normally emerged.

Fertility of Eggs and Duration of Mating.

The table shows the fertility of the eggs in relation to the time spent in copulo. All those which continued for about the normal length of time, 16 hours or more, behaved naturally and severed of their own accord; the others (3 to 15 hours) were for the most part artificially separated to ascertain the effect of the shortened period upon the fertility. The table is divided into first day's deposit, second day's deposit, etc., after mating.

An inspection of the columns reveals that there is absolutely no relation between the period of copulation and the fertility of the eggs.[1] We find that the insects which remained in copulo from 3 to 15 hours deposited just as large a per cent. of fertile eggs, and also as large actual numbers, as those which continued from 18 to 48 hours. Hence our present material at least would lead us to conclude that the first three hours are quite sufficient, and that a longer period is only a waste of valuable time and vitality. Especially does this seem distinctly disadvantageous to the species when we consider the number of eggs which the females produce but can not deposit in their short lives. If females which remain in copulo only 3 hours deposit as large a per cent. of fertile eggs as those which continue for 24 hours or more and afterward die without completely ovipositing, it would seem as though natural selection had missed its mark in not shortening the period of copulation and thereby lengthening the chance for oviposition.

[1] The per cents of fertility were also calculated and tabulated for each individual of the entire lot, but these also showed no relationship whatsoever. Since the data are submitted it was thought superfluous to publish these per cents here.

♀ No.	Hours in Copulo.	1st Day's Deposit.				2d Day's Deposit				3d Day's Deposit.				4th Day's Deposit.				5th Day's Deposit.				6th Day's Deposit.				7th Day's Deposit.				Total.			
		T.	F.H.	F.U.	Inf.	T.	F.H.	F.U.	Inf.	T.	F.H.	F.U.	Inf.	T.	F.H.	F.U.	Inf.	T.	F.H.	F.U.	Inf.	T.	F.H.	F.U.	Inf.	T.	F.H.	F.U.	Inf.	De-posit.	F.H.	F.U.	Inf.
1	3	166	138	25	3	20	0	20	0	14	1	13	0	13	0	13	0	10	0	6	4	—	—	—	—	—	—	—	—	223	139	77	7
2	3	99	92	1	6	121	97	19	5	45	20	5	20	8	0	7	1	—	—	—	—	—	—	—	—	—	—	—	—	273	209	32	32
3	3	181	148	3	30	128	101	24	3	26	25	1	0	17	8	2	7	3	0	3	0	—	—	—	—	—	—	—	—	355	282	33	40
4	3½	205	169	25	11	83	7	73	3	44	1	0	43	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	332	177	98	57
5	4	189	158	2	29	?	?	?	?	?	?	?	?	?	?	?	?	42	30	7	5	6	4	0	2	—	—	—	—	237	192	9	36
6	4	80	62	2	16	96	69	19	8	62	6	47	9	?	?	?	?	1	0	0	1	—	—	—	—	—	—	—	—	239	137	68	34
7	4	140	132	0	8	120	118	1	1	6	4	2	0	2	1	1	0	1	1	0	0	—	—	—	—	—	—	—	—	269	256	4	9
8	5	89	86	0	3	62	3	58	1	27	8	16	3	?	?	?	?	1	0	1	0	—	—	—	—	—	—	—	—	179	97	75	7
9	12	20	14	0	6	68	53	2	13	95	93	1	1	21	18	1	2	10	7	1	2	—	—	—	—	—	—	—	—	214	185	5	24
10	2+8*	24	12	1	11	95	89	0	6	37	28	7	2	82	79	2	1	34	32	2	0	8	8	0	0	—	—	—	—	280	248	12	20
11	12	155	143	1	11	67	60	1	6	11	11	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	233	214	2	17
12	12	94	63	8	23	104	98	1	5	?	?	?	?	151	146	1	4	—	—	—	—	—	—	—	—	—	—	—	—	349	307	10	32
13	13	20	17	1	2	150	42	9	99	4	3	0	1	7	5	1	1	7	5	2	0	51	24	11	16	28	4	2	22	267	100	26	141
14	14	71	71	0	0	26	24	2	0	8	0	0	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	105	95	2	8
15	14	81	57	4	20	255	245	2	8	55	44	4	7	15	6	7	2	3	0	3	0	—	—	—	—	—	—	—	—	409	352	20	37
16	14	12	9	1	2	46	38	6	2	55	50	5	0	47	30	16	1	—	—	—	—	—	—	—	—	—	—	—	—	160	127	28	5
17	14	77	61	8	8	220	206	8	6	82	73	4	5	27	11	7	9	—	—	—	—	—	—	—	—	—	—	—	—	406	351	27	28
18	14	69	33	3	33	130	105	5	20	23	17	5	1	7	3	1	3	—	—	—	—	—	—	—	—	—	—	—	—	229	158	14	57
19	14	166	126	3	37	91	84	3	4	114	110	2	2	4	1	3	0	28	5	23	0	—	—	—	—	—	—	—	—	403	326	34	43
20	15	93	83	3	7	57	43	9	5	114	105	6	3	70	60	3	7	19	2	17	0	4	0	4	0	—	—	—	—	357	293	42	22
21	16	112	11	1	100	110	35	5	70	84	77	7	0	29	21	8	0	—	—	—	—	—	—	—	—	—	—	—	—	335	144	21	170
22	18	140	126	2	12	63	55	4	4	26	17	9	0	12	7	5	0	5	0	5	0	—	—	—	—	—	—	—	—	246	205	25	16
23	24	131	125	5	1	92	68	20	4	30	7	4	19	42	42	0	0	—	—	—	—	—	—	—	—	—	—	—	—	295	242	29	24
24	24	123	0	0	123	41	0	0	41	15	11	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	179	11	2	166
25	24	158	5	17	136	32	20	9	3	27	16	10	1	16	13	2	1	10	5	5	0	—	—	—	—	—	—	—	—	243	59	43	141
26	24	114	77	17	20	82	80	2	0	12	11	0	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	208	168	19	21
27	24	190	135	51	4	74	40	32	2	31	15	16	0	33	21	9	3	—	—	—	—	—	—	—	—	—	—	—	—	328	211	108	9
28	24	111	0	0	111	121	0	4	117	28	7	0	21	2	1	0	1	—	—	—	—	—	—	—	—	—	—	—	—	262	8	4	250
29	24	56	0	0	56	41	0	0	41	25	0	0	25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	122	0	0	122
30	24	165	5	6	154	48	18	3	27	9	5	2	2	?	?	?	?	3	0	0	3	—	—	—	—	—	—	—	—	225	28	11	186
31	48	77	45	26	6	3	3	0	0	3	3	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	80	48	26	6
32	?	36	18	1	17	3	2	0	1	58	0	0	58	49	0	0	49	47	0	0	47	53	0	0	53	3	0	0	3	249	20	1	228
33	?	240	184	31	25	2	0	2	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	242	184	33	25
34	?	78	55	10	13	81	74	5	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	159	129	15	15
35	?	121	95	10	16	132	102	5	25	49	2	29	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	302	199	44	59

T. = total. F.H. = fertile eggs that hatched.

F.U. = fertile eggs unhatched. Inf. = infertile eggs.

* In copulo two hours one day and eight hours the next.

Furthermore, it is found that when the percentages of fertility of each day's deposit are calculated, in two thirds of the individuals the fertility increases as the days go by, while in only one third is there a decrease. Hence we are forced to admit another heavy loss; for this evidence would lead us to conclude that a large proportion of the eggs retained after death were also probably perfectly good.

In the material here considered we find also no correlation between this phenomenon and the long or short duration of copulation.

The table shows that in some of the cases of prolonged mating, the first day's deposit of eggs contained a great number which were infertile. Why this should be has not been ascertained. Being confident that all eggs laid previous to mating were destroyed, we are at a loss to explain why the first eggs, which one would think had the best opportunity of being fertilized, were otherwise. But a stranger fact still is that while female 29 was in copulo 24 hours, not one egg was fertile, and almost the same condition existed in females 24, 28 and 30.

One might think that those insects which carried an abnormally large number of eggs would have less chance for their complete fertilization. According to the data in our table, however, no such relation is found to exist. In fact the high percentage of fertility in many of these cases might suggest that the vigorous condition of the female contributed more toward insuring the fertility of the eggs than did the amount of sperm or the duration of copulation.

In all of the eggs in these experiments, then, 77 per cent. were fertile and 23 per cent. infertile. In the next to the last column of the table is given the number which partially developed but, from some unknown cause, died in the shell before hatching. These constitute 14.5 per cent. of the fertile eggs, or 11 per cent. of the whole number deposited after mating. All of the eggs were kept under identical conditions, so if 85.5 per cent. of the fertile ones hatched, the fact that these 14.5 per cent. did not hatch can not be attributed to environmental conditions.

Some of the eggs are laid in closely adhering clusters, and some are dropped singly. It was suspected for a time that the cater-

pillars had more difficulty in emerging from the clustered eggs and that many died in the attempt, but it was soon found that as many died in the shell in the loose as in the adhering eggs.

Hence the proportion which go to the wall even up to the time of emerging is large. We are reminded of Darwin's[1] statement that the ". . . geometrical tendency to increase must be checked by destruction at some period of life . . . and this period in the great majority of cases is an early one. . . . But if many eggs or young are destroyed, many must be produced or the species will become extinct." In our present material it would seem that nature, in making the attempt at providing so bountifully for the perpetuation of the species, has overstepped the limits of real economy by wasting so much unfinished material.

[1] "Origin of Species," 6th ed., p. 52, 1887.